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INDUSTRIAL SAFETY HAZARD REDUCTION THROUGH PERFORMANCE FEEDBACK

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A "feedback package" system, designed to prevent occupational accidents and to fit directly into the normal operations of an industrial organization, was analyzed. Eighteen hazardous conditions in six production departments were assessed during seven observation sessions over a 12-week period, plus four follow-up observations over 4 months. The "feedback package" was presented in multiple baseline fashion, across subjects (department supervisors). It consisted of presenting the supervisor with copies of observational data, accompanied by a note which congratulated good practices and suggested ways for improving safety conditions, along with occasional comments from a senior executive. The results indicated that during the feedback phase, hazard rates were lower and less variable than during the baseline phase. Baseline data were highly variable with peaks ranging from 20 to 55 hazards per department. Following intervention, hazard frequencies dropped by 60%, averaged across departments, with decreases ranging from 29% to 88%. During treatment, data stabilized, with the highest frequency reaching 33. A modified feedback system was implemented by the organization following termination of the study, validating the assumption that such a system would tend to maintain.

DESCRIPTORS: industrial safety, feedback, organization, hazard reduction

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Industrial accidents in the United States are the fourth leading cause of death—after heart disease, cancer, and strokes (*Accident Facts,* 1979). Accidents cost billions of dollars annually for treatment of over ten million injuries, lost occupational time, insurance administration, and other related costs. Of such accidents, a large proportion occur in the occupational setting. In 1978, for example, there were 13,000 deaths and 2,200,000 job-related disabling injuries (*Accident Facts,* 1979).

However, it is only quite recently that behavioral research has begun to address the topic of industrial accidents, augmenting the traditional safety literature, which had tended to emphasize hazard and risk classification and the development of safety intervention programs. The contribution of behavior analysis has been the precision with which safety programs have been implemented and their effectiveness measured. Komaki, Barwick, and Scott (1978) trained and reinforced the improved safety behaviors of bakery workers. In the shipbuilding field, Uslan (Note 1) instituted a program in which supervisors were trained in observational recording and in the use of reinforcement for the behavior of wearing safety devices such as gloves and glasses. Ritschl, Mirman, Hall, and Sigler (Note 2) used an incentive program called "protective poker" and supervisor training in positive and corrective feedback to reduce injuries in a chemical plant. Although not in an industrial setting, Pierce (Note 3) applied behavioral principles to the improvement of safety conditions in an institu-

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tion for retarded adults and Parsons (1976) used conditioning methods to teach drivers to follow safety precautions. Sulzer-Azaroff (1978) tested a program in a group of university research laboratories in which informational feedback about hazards delivered about every 3 or 4 weeks resulted in the reduction of hazards.

Probably one reason that behavior analysts have done little research in industrial safety has been the problem of identifying an appropriate dependent variable. Continuously monitoring all worker operations and recording those classes of behavior that lead to accidents would be the most direct measure having clearly apparent face validity. Such an approach, however, would be pragmatically unfeasible requiring almost infinite time, effort, and skill in detecting an accident in progress. A second method would be to record those classes of behavior that have been correlated with accidents in the past, such as operating a machine without using a safety guard or failing to use protective clothing when conditions warrant. Such an approach is most applicable in a large plant where a large number of workers are busily occupied. In such settings, it should be possible to record sufficient rates of unsafe practices to demonstrate behavior change as a function of an effective intervention. (This was the approach taken by Komaki et al., 1978 and Uslan, Note 1.) A third alternative (e.g., Sulzer-Azaroff, 1978) is one that does not focus on behavior at all, but rather on the products of unsafe practices: physical safety hazards such as blocked passageways or unstable stacks of materials. That system, though perhaps occasionally failing to detect an unsafe practice, does have some clear advantages. Recording can be performed at a reasonable cost—rapidly and unobtrusively. It simply requires that an observer survey the plant for locations and frequencies of safety hazards. (These advantages should have particular relevance for small plants that have a higher per capita rate of accidents than large ones, *Accident Facts,* 1979). Because the reduction in numbers of hazards can be expected to diminish rates of accidents, a presumption underlying traditional safety efforts (Wigglesworth, 1972), this alternative was selected for the present study.

This study constitutes a *systematic replication* of the Sulzer-Azaroff (1978) experiment (Sidman, 1960). That study took place in a group of university materials research laboratories, where reinforcing or aversive contingencies operating on the behavior of subjects (generally, social approval or disapproval for tenured faculty) were quite different from those operating on the behavior of employees in an industrial firm (major personnel actions). Subject differences between the two settings were also striking, with major dissimilarities in occupational function, sex, educational and sociocultural background. In the present study we attempted to show more immediate results by intervening early and more often. As in the 1978 study, we attempted to design a program based on feedback that could be incorporated smoothly within the ongoing operation, with minimal time required for program preparation and implementation.

Feedback alone, or combined with approval, has been used in various behavioral programs applied to industry (Emmert, 1978; Feeney, 1972; Mitchell, 1976; Rettig, 1975; Runnion, Johnson, & McWhorter, 1978). Since feedback accompanied by approval of and suggestions for improvement has thus demonstrated its effectiveness as a simple, direct strategy for an industrial setting, it was decided to test a "feedback package" consisting of these elements, in a small industrial plant. The purpose of the study was to analyze the reliability and generality of the feedback in reducing safety hazards during the experiment as well as on follow-up and to determine if the intervention and any correlated improvement would persist following formal termination of the study.

METHOD

Subjects

Four female and two male production supervisors of the main plant of a small industrial

Table 1
Description of Departments and Supervisors

Department				Supervisor					
No.	*Task*	*Size (square feet)*	*Number of machines*	*Age*	*Sex*	*Seniority*	*Time in current position*	*Workers supervised Male*	*Workers supervised Female*
1	screen printing, hot stamping, and embossing	3,100	16	23	F	5 years	15 months	4	5
2	heat sealing	4,500	42	55	F	10 years	3 months	3	32
3	cutting and assembly	5,000	33	34	M	1 year	[a]	9	7
4	fabrication of credit and ID cards	5,000	32	46	F	10 years	5 years	1	43
5	packing finished products	1,000	0	60	F	15 years	10 years	–	5
6	receiving and distributing raw materials	2,000	0	24	M	6 months	3 months	6	–

[a]Assumed supervisor responsibilities during 9th week of experiment.

organization gave their signed informed consent to participate in the experiment. (Demographic data on the supervisors are presented in Table 1.) All supervisors but one participated in the study throughout. A management decision to change the supervisor for Department Number 3 occurred in the ninth week of the experiment, prior to implementing the feedback system in this department. The new supervisor was then given pretreatment explanations and asked to participate and to sign the consent form. The data presented in Table 1 for the supervisor for Department Number 3 are the data for the new supervisor. All the supervisors belonged to the safety committee. Thus, they could identify hazards as they had been in charge of doing safety inspections before the study. The hazard list used in this study was constructed both with their help in keeping with Occupational Safety and Health (OSHA) standards.

Setting and Personnel

The study was conducted in the main factory of a private industrial organization that developed and manufactured custom-fabricated products. It was located in a New England town of approximately 30,000 people. The company had 230 employees, who worked in three different locations, with management offices located in the main factory. The safety program focused only on conditions in the production areas of the plant and the 128 people assigned to those areas.

The plant had a working space of approximately 2,400 m^2 and was divided into six major production departments plus a machine shop, dark room, a developing production department, and a dining area. Each department was assigned a supervisor, who reported directly to the Production Manager. He in turn reported to the General Manager.

Of the six departments, three were physically enclosed by brick walls or wire fencing, and open walkways permitted access from one department to another. The other three were open areas, separated from each other by storage racks. Walkways and aisles were clearly marked by yellow lines on the floor. Table 1 illustrates the size, number of machines, and main function of each department. Three departments (Two, Three, and Four) operated on a double shift.

Each department had its own set of potential hazards. For instance, due to their location, some departments had no fire exits to keep clear, no flammable materials closet to keep closed, or no machines to guard. Only in Departments One and Three was there the potential for all these hazards. Departments Five and Six did not use any industrial machinery requiring safeguards.

Each week workers were given their departmental assignments. Approximately 8% of the workers changed departments each week. The supervisor assigned work every morning according to the production plan received from the Production Manager.

A woman (the co-author), with a background both in applied behavior analysis and industrial management (hereafter referred to as the Experimenter), conducted the operation of the project. Initially, primary and reliability observers were two undergraduate males who had had previous technical experience with applied behavior analysis programs. A third observer, a graduate student of economics, substituted as primary observer for the last half of the project.

The Personnel Manager participated in the development of the safety checklist, provided safety data, and managed the feedback system. Both Production and Materials Managers developed and implemented specific suggestions to modify hazardous conditions, and distributed the feedback form. The Vice-President verbally praised department supervisors when the number of hazards in their respective departments had been considerably reduced.

Ten staff members constituted the safety committee: the six supervisors, the Personnel Manager, the Set-up Supervisor, the Chief Engineer, and a Machine Shop worker. Its main role was to conduct unannounced monthly inspections to identify existing hazardous conditions in each department. After inspection, a written memo notified each department's supervisor of the identified hazards. (During the study, the experimental procedure was substituted for that standard operation.)

Apparatus and Materials

The apparatus and materials used in the study consisted of the following:

1. Observational recording sheet consisting of a list of 18 hazards and an individual map of each department's layout.
2. Weekly data summary chart: A chart with the list of hazards and the daily total observed in each department was used to summarize each week's data.
3. Feedback/suggestion forms: The feedback form, typed on company letterhead, listed the frequency of hazards recorded on a particular day compared with previous feedback. Congratulatory or corrective comments were added when hazards had either decreased or increased, respectively. An observation form was attached, indicating the type and location of the hazard and suggesting ways of eliminating it.

Observational Recording

Throughout the experiment, measures were taken of frequency, type, and location of hazardous conditions found in each department, as defined by the hazard checklist and map on the observation form.[1] Although the most serious hazards had been corrected prior to the study, various less dangerous hazards persisted. Using Occupational Safety and Health Act (OSHA) terminology and hazard classifications, and with the assistance of several members of the Safety Committee, a list of possible hazardous conditions was developed. Six major categories included: (1) Obstructions of walking-working surfaces; (2) Exit, ladder, or sprinkler obstruction; (3) Hazardous materials; (4) Hazardous materials storage; (5) Hazardous machine guarding; and (6) Electrical hazards. These categories were subdivided into 18 specific hazardous conditions to permit precise feedback.

Data were recorded at randomly chosen times once each day, 5 days a week, for 12 weeks (except during weeks 4, 5, and 11, when 4 observations were conducted). Observations took place during the first shift while the plant was in full operation, sometime between 8:30 a.m. and 3:30 p.m. Each observation session lasted from 15 to 20 min. Initially, observations were sched-

[1]A complete set of the detailed hazard categories may be obtained from the authors.

uled at one specific time; however, major differences were noted in the production process between mornings and afternoons. To obtain a more representative sample, therefore, observation times were scheduled randomly throughout the shift. This also kept supervisors from preparing for the visits, thereby invalidating the data. To minimize such predictability even further, a toss of a coin determined whether observations should start on the left or the right side of the factory.

The observer walked through each department, observing hazards, but did not record them until reaching the end of each aisle. (This procedure was designed to prevent the workers from noticing exactly what was being recorded.) If there were any doubts, the site would be revisited for clarification. The location of each hazard and its frequency of occurrence was then recorded on the map.

Observer training consisted of teaching them to identify and record each particular hazard. Written information on OSHA standards was provided to familiarize observers with terminology and types of hazards, along with examples of types and numbers of hazard classifications. Observers practiced scoring selected sample areas independently until an 85% agreement level on occurrence was reached. In each of these trial observations, disagreements were discussed and both the list and definitions were refined.

Reliability was assessed at least once a week for a total of 12 times during the study. Two observers would inspect the same area at the same time, marking the number and location of hazards on their sheets, without communication. Data sheets were then compared and, if both observers recorded the same number of occurrences for a particular hazard in the same place, an agreement was scored. If one indicated the presence of a hazard, and the other did not or if the number or location of occurrences differed, a disagreement was scored. Reliability was calculated by dividing the number of agreements on occurrence of hazards by the number of agreements plus disagreements multiplied by 100. The mean percentage of agreements between observers across 12 weeks of data collection for each department was as follows: Department One—93%; Department Two—98%; Department Three—92%; Departments Four, Five and Six—90%. Overall observer reliability averaged 94%, with a range from 83% to 100%.

Design

A multiple baseline across-subjects (department supervisors) design (Baer, Wolf, & Risley, 1968) was used to assess the impact of the independent variable (feedback and approval or corrective suggestions) on the frequency and types of hazards. Baselines were recorded on the frequency and type of hazards of all six departments for 3 weeks. Feedback was then implemented with Departments One and Two, while baseline conditions were continued with the other four departments for the next 6 weeks. This sequence was then replicated with Departments Four and Five, and after 9 weeks with Departments Three and Six.

Two major factors were considered in assigning supervisors to the first feedback condition, viz., hazard frequencies (this meant choosing among Departments One, Two, or Three) and potential for generalization across departments. To minimize the latter, the two departments that were physically close together and were apt to interact more frequently were chosen for the first feedback condition. The supervisors were requested not to communicate to others about the feedback program. Later, assignments were made at random.

Intervention

The intervention consisted of a three-component "package": (1) feedback as to number and location of hazards; (2) specific suggestions for improvement; and (3) any positive evaluative comments merited by accomplishments. It took an average of 7 min to prepare each form. Written feedback was given on company paper at a short meeting held with the Production and/or Personnel Manager and the respective supervisor. In these meetings, the feedback was conveyed orally or progress was emphasized orally as well as in writing. Threat or punishment was *never* used. Approval statements were written in the feedback form and delivered orally by a company Vice-President on a few occasions.

Because management felt that a semiweekly schedule could be maintained following termination of the formal experiment, it was decided to provide the feedback twice a week. The results of Monday's and Thursday's inspections were presented on Tuesdays and Fridays.

To ensure that supervisors understood the system, individual meetings were held with each of them prior to implementing the feedback package in their departments. The Personnel and Production Managers and Experimenter were also present. The supervisor was asked to read the form to make sure it was clear, and questions were solicited and answered. Supervisors were told they would be receiving similar feedback twice a week henceforth, and they were asked to keep the system confidential for the time being. In order to imbue the "package" with administrative support, the Production Manager distributed the feedback.

Since there was a high frequency of "waste and unused equipment obstruction," the Materials Manager was also designated to receive a copy of the feedback-suggestion form. Also, the "set-up" person and the Chief Engineer received copies of the feedback-suggestion form on those occasions that required their cooperation.

During the second week of treatment (Session 19), the Materials Manager took the initiative of calling a meeting with all supervisors to emphasize the need for keeping aisles clear of obstructions. This unplanned event delayed the introduction of treatment with the next group for an additional week, while the data returned to previous baseline levels. Another unplanned event, a safety talk to supervisors of Departments Three and Six took place following Session 29.

Posttreatment and Follow-up Procedures

Following the last experimental session (56) the Experimenter held a meeting with the Safety Committee members and the company Vice-President to review the program and present the results. After explaining graphs of group and individual results, questions were answered and a tentative continuation program was planned. The Committee agreed that two of its members (volunteers) should be trained to use the recording system once a week (rather than twice). Because observations were to be done more often than the once a month (as had been done prior to the experiment), the volunteers were to rotate twice a month. Training was conducted as described previously.

Four follow-up sessions were conducted following the formal experiment. These occurred 3 days after the last experimental data collection session and 2 weeks, 6 weeks, and 4 months later.

RESULTS

Data on hazard frequency for all six departments are presented in Figure 1. First it should be noted that two events appeared to be followed by a temporary decrease in hazards: an unplanned managerial meeting devoted to safety following Session 19 and a safety talk by management to the supervisors of Departments Three and Six following Session 29. (See data for the subsequent sessions depicted by open circles in Figure 1.) Overall, results were similar for all departments in that the mean frequency of hazards decreased during treatment, when compared with their baseline levels.

During baseline, the mean frequency of hazards in Departments One and Two was 30.1 and 28.8, respectively. This decreased to 13.2 and 5.7, respectively, during the treatment phase, but hazards among the other two groups remained approximately at baseline levels. The range of hazards during baseline varied from a low of 21 and 15 for Departments One and Two to a high

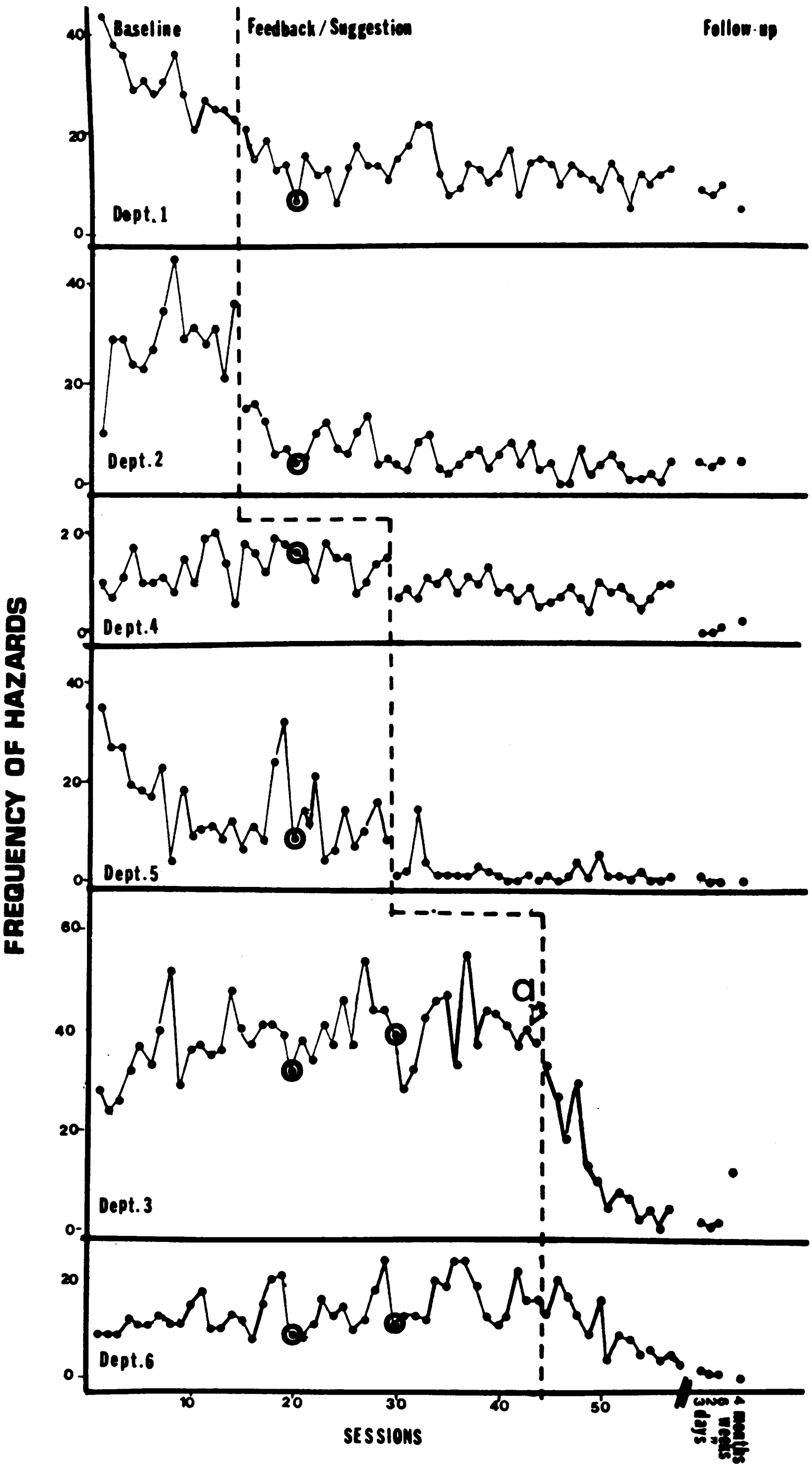

Fig. 1. Frequency of hazards across department as a function of the introduction of the "feedback package." Data for days following unplanned safety meetings are indicated by an open circle. At point "a" there was a change in supervisors.

of 44 and 45, respectively. In Department One a downward trend was observed during baseline and continued during treatment. The hazard frequency range during treatment varied between 5 and 22 for this department and reached baseline levels on three occasions. Although in the first three baseline sessions the average number of hazards was 39.3, in the last three sessions this average fell to 12.6. The initiation of the intervention was paired with a rapid decrease in the number of hazards in Department Two, which remained at a low level throughout. The range varied between 0 and 16 during treatment.

The mean frequency of hazards for Departments Four and Five was 13.2 and 14.8 during basesline, decreasing to 8.4 and 1.8, respectively, during the feedback-suggestion phase. Hazard frequency ranged from a low of 6 and 4 to a high of 20 and 35 for Departments Four and Five, respectively, during baseline. During treatment, the range of each varied between 4 and 0 to 13 and 14.

The mean frequency of hazards in Departments Three and Six decreased from a baseline level of 38.6 and 14 to 12.9 and 9.9, respectively, during treatment conditions. The range of hazards varied during baseline from a low of 24 and 8 to a high of 55 and 24, respectively, and during treatment from 0 to 4 to 33 and 20, respectively. In Department Three, hazards decreased considerably when the feedback-suggestion phase started. A downward trend was observed throughout treatment and maintained during follow-up, although hazard frequency increased slightly during Session 48 when a general inventory was being performed.

DISCUSSION

The results of this study suggest that a simple, natural "feedback package" can be effective in reducing frequencies of specific hazards in a small industrial plant. Although ongoing behavior was not formally assessed, one could assume that both supervisor and worker behavior changed during the course of the study. Supervisors received the feedback directly but in order to implement the suggested changes and decrease number of hazards, they had to ask the workers to follow the suggestions. (Informal observations supported this assumption.) Presumably that reduction in hazards would tend to prevent accidents. (Although accident rates were not experimentally compared in this study, there were no accidents serious enough to require workers to absent themselves from work during the course of the project.) As Komaki et al. (1978) found in industry and Sulzer-Azaroff (1978) found in a science research laboratory, feedback was apparently effective in improving safety practices.

As in the Sulzer-Azaroff (1978) study, there appeared to be some positive spin-off effects accompanying the present program. For instance, it was informally observed that a more careful array of materials gave the plant a neater appearance. There was also an increase in meetings dealing with safety-related issues and workers began to pose many questions about safety practices. Some organizational changes also took place. The Production Manager, who was not initially involved with safety-related problems, volunteered to follow through with the program and to become actively involved in it. Furthermore, when one member of the committee suggested a return to monthly inspections, the Personnel Manager and some supervisors clearly rejected this in favor of at least weekly inspections.

Industrial management is primarily concerned with production. Thus, for any adjunct program to be accepted, it should either enhance production or at least not affect it adversely. This specific safety program, while neither intending nor intervening directly to increase production, may have indirectly had that effect. Besides preventing accidents and, consequently, loss of time on the job, it may well have aided production in other ways also. For instance, in Department Number 3 (Cutting and Assembly), following a "safer" arrangement of materials once the treatment phase had started, productivity was observed to increase in that department.

The primary value of the program, however, was its simplicity and the ease with which it could be incorporated within a supervisor's routine. Once hazards were identified and defined (the major effort required by the program), inspections were carried out in about 10 to 15 min and it took only a few minutes to fill in each form. The same forms were used for observations and feedback, and no extensive training or expertise was required of plant safety inspectors. Such ease of implementation is promising for successful maintenance of a program following the termination of formal experimentation. A long-range follow-up 4 months after the completion of the experimental intervention phase of this study indicated a highly favorable maintenance effect, thus supporting the above assumption.

With this demonstration that a semiweekly feedback schedule can reduce industrial hazards, presumably thereby contributing toward accident prevention, future research might turn to some related questions: What factors will tend to promote use of such systems by other industrial organizations? What are the specific costs in dollars and time of such a program? How important to the successful implementation and maintenance of the program are such variables as cost, time, the nature of the task, lines of authority or contingency networks, and others. What are the contributions made by various components of the "feedback packages"? Answers to these and related research questions could conceivably have a significant impact on one of the most serious concerns of today's society—the prevention of occupational accidents.

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